ENERGY STAR® Labeling Potential for Water Heaters

U.S. Department of Energy

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Executive Summary

With a new Federal water heater standard set to go into effect on January 20, 2004, it is a good time for the U.S. Department of Energy (DOE) to implement an ENERGY STAR program to promote products that exceed this new standard. A variety of water heating technologies exists, each with widely varying capital expenses and energy performance. The research detailed in this document explores the possibilities for ENERGY STAR water heater criteria.

This paper explores the different approaches that DOE could pursue in labeling water heaters, and the potential advantages and disadvantages of each. The goal of this document is to solicit commentary and build consensus toward a final water heater criteria.

Two primary ways ENERGY STAR water heater criteria may be developed are discussed. The first potential approach would be to include best-performing, conventional water heating products in each major water heater product class as defined by DOE in standard setting. This method would include all manufacturers and allow customers to participate immediately. The national aggregate savings would be significant. Solar and heat pump technologies could be included in this approach, phased in over time, or excluded.

A second potential approach would be to include only the advanced electric and best-performing gas and oil water heating technologies. Solar and heat pump technologies would be the only qualifying products in the electrical storage product class since they so greatly outperform electrical resistance technology from an energy perspective. The best-performing gas and oil storage and gas instantaneous water heaters would also be included in their respective product classes. The second approach could generate tremendous energy savings if giving the ENERGY STAR designation only to solar and heat pump (and not to electric resistance) water heaters increased the market penetration of these technologies beyond what it would be if the ENERGY STAR label was also given to the best-performing electric resistance technology.

However, there are concerns with immediately including these advanced technologies in ENERGY STAR criteria. Heat pump, solar, and instantaneous water heaters have high capital expenses and underdeveloped market infrastructures. They also may suffer reliability concerns typical of emerging or advanced technologies that may limit consumer and manufacturer participation. Developing ENERGY STAR water heater criteria that includes these technologies could motivate both consumers and manufacturers to pursue the best water heating technologies. Greater market demand may lead to greater production and reduced product cost in the future. Including each of these technologies in an ENERGY STAR program, however, may be premature given the state of the technologies at this time.

ENERGY STAR promotes efficient technologies, but also seeks technologies that are reliable, available, and economically feasible for the average consumer. The Department is seeking stakeholder comments on the feasibility of including these technologies given their market status, capital expense, and reliability concerns.

ENERGY STAR Water Heater Criteria Options

1. ENERGY STAR Water Heater Criteria for the Best-Performing Conventional Water Heating Technologies

Scope

Initial criteria including electric resistance and gas/oil storage water heaters is a possible first step toward ENERGY STAR water heater criteria allowing all manufacturers and consumers to participate. This approach could also include gas instantaneous water heaters.

Currently, the marketplace does not offer electric instantaneous water heaters that meet household hot water needs. Therefore, this product class likely would not be included in ENERGY STAR water heater criteria. Tabletop water heaters have a very small market share and would not be likely be included.

Solar and heat pump water heaters could be eligible to qualify in the electrical storage water heater product class along with conventional products, either immediately or after a phase-in period of two or more years.

Potential Performance Criteria

Manufacturers are responding to the new Federal standard with more efficient product offerings. The Gas Appliance Manufacturer Association's (GAMA) October 2002 water heater directory shows many products exceeding the current Federal minimums by a few percentage points. DOE would set criteria based on widely available, conventional products. Anticipating the new Federal standard, the GAMA database was filtered for units meeting the new Federal standard. In addition, any duplicates resulting from OEM or labeling agreements were eliminated for the analysis. For instantaneous gas water heaters, the Federal Trade Commission's list of units was used, along with some data supplied by manufacturers. Using these filtered databases and applying statistical analysis, the performance levels in the following table were determined. The table also summarizes potential energy savings for ENERGY STAR criteria for four of the six Federal water heater product classes.

Product Class	Potential ENERGY STAR Minimum Energy Factor (EF)[1]	Potential ENERGY STAR EF for Common Size[5]	2004 Federal Minimum EF for Common Size[5]	Qualifying/ Available Models[2]	National Savings @ 10% Market Share (GBtu)
Electric Storage[4]	0.964-0.0007*volume	0.93 (50 G)	0.90 (50 G)	73/178[3]	260
Gas Storage	0.696-0.0017*volume	0.63 (40 G)	0.59 (40 G)	81/296	814
Oil Storage	0.613-0.0017*volume	0.56 (30 G)	0.53 (30 G)	10/13	4.9
Gas Instantaneous	0.82	0.82 (NA)	0.62 (NA)	8/28	29

[1]See page 6 for a discussion of energy factors.
[2]Available models are unique (OEM duplicates eliminated) and meet the 2004 Federal standard.
[3]Only electric storage is shown, but all heat pump water heaters and solar water heaters will qualify as well.
[4]Heat pump water heaters and solar water heaters would qualify under this product class. The savings estimate includes the contribution of both.
[5] Common sizes are based on industry commentary

The total, national energy savings for the above selected performance levels is 1.1 TBtu-site. The potential ENERGY STAR minimum energy factor (EF) is calculated based on the storage volume of the tank, just as the Federal standard calculates the energy factor. (Energy factors are the way energy efficiency is expressed for water heaters.) The potential ENERGY STAR energy factor for common size simply enters the most common volume for a given product class to show the resulting potential ENERGY STAR energy factor.

Manufacturers will be changing their product offerings throughout the coming year given the anticipated Federal standard change, water heater industry mergers resulting in changing product lines, new water heater safety regulations becoming effective this year, and the potential effective date for the ENERGY STAR water heater criteria. Therefore, as the criteria development progresses, the minimum energy factors chosen may need to be reevaluated. The Department is interested in formal commentary on the potential energy factor levels for all water heating technologies so that it can more accurately determine energy factor levels for ENERGY STAR in the future.

Oil, Gas, and Electric Storage Water Heater Technologies

Conventional gas and electric storage technologies dominate the marketplace. The electric storage units use one or two electric elements to heat water. The gas storage unit uses a single burner in the center of the tank. Improving the performance of the storage unit can be achieved in four basic ways:

- Adding heat traps
- Insulating the tank bottom

- Adding flue baffles
- Increasing insulation

Each of these measures increases the cost. From the latest water heater technical support document (TSD) used to develop the current Federal standard, DOE chose Trial Level 3 for the basis of the new standard. To achieve this performance level, electric storage units would require heat traps, bottom insulation, and 2" insulation; gas storage units would require heat traps, flue baffles, and 2" insulation. The TSD determined these changes to be cost effective.

Manufacturers may pursue any of these changes to increase the energy performance of their products. The GAMA directory indicates that many products exceed the new Federal minimum already, implying that modifying existing products is possible and cost effective.

The Federal Trade Commission's (FTC) EnergyGuide displays a storage water heater's first hour rating (FHR), energy consumption per year, model number, and energy factor. The efficiency of storage water heaters is defined by the energy factor. The energy factor is defined as the ratio of the energy delivered to the water over the energy put into the tank, including standby losses. Manufacturers must self test their equipment according to 10CFR430, subpart B, appendix E to determine the energy factor; results are submitted to the FTC. The energy factor can be used to predict how much energy a unit will use in one year. The equations are provided below:

- Gas and Oil: $EstimateAnnualCostofOperation = \frac{41{,}045 Btu}{EF} x(\$ / Btu) x365$

- Electric: $EstimateAnnualCostofOperation = \frac{12.03 kWh}{EF} x(\$ / kWh) x365$

Once manufacturers establish the energy factors for a product, they use the above equations to estimate the energy consumption for the FTC EnergyGuide labels. The minimal performance equations for storage types depend on the volume (gallons) and are shown below:

- $EF_{electric}$=0.97-0.00132*Volume
- EF_{gas}= 0.67-0.0019*Volume
- EF_{Oil}=0.59-0.0019*Volume

Note that the energy factors for water heaters depend on the storage volume (gallons) of a water heater, not the FHR.

Condensing, Gas Storage Water Heaters

Residential-type gas condensing water heaters currently have limited availability, but the commercial market is brisk. Most manufacturers commented that they couldn't presently make a cost-effective residential gas condensing water heater.

Gas and Electric Instantaneous Water Heater Technologies

DOE has added gas and electric instantaneous water heaters to the new 2004 Federal standard by applying the 1991 storage-type water heater standards for minimum energy factors. In making this decision, DOE said that the products did not warrant more extensive analysis for standards setting since instantaneous water heaters comprised less than one percent of the water heater market at the time of the analysis. However, these products could be reexamined in the future if their market growth warrants.

The DOE test procedure requires instantaneous water heaters to list the maximum gallons-per-minute (GPM) draw rate instead of the first hour rating. FHR is used for sizing a storage-type water heater, but did not translate well to instantaneous water heaters. Any manufacturer of instantaneous water heaters may list its maximum GPM rating and energy factor on the Federal Trade Commission's yellow EnergyGuide label. The maximum GPM draw rating is a better way to size an instantaneous water heater to ensure that its capacity meets whole-house requirements.

Currently, only gas instantaneous water heaters can produce the approximate 3 gpm of flow at 135F (77F rise) required by the typical household for whole-house service and remain within the standard maximum fuel input limitation of 200 kBtu/h (59 kW). Units above the 200-kBtu/h (59-kW) limit are available, but were not considered at this time since the Federal standard does not govern them.

Gas instantaneous water heaters will place a much greater demand on the gas supply line. Consumers should consult an expert when installing these products, especially in older homes to ensure that the gas infrastructure can support the application of such water heaters. Local gas utilities may be able to help consumers with installation. Consequently, DOE could limit ENERGY STAR criteria to gas instantaneous water heaters being used in new construction.

Electric instantaneous water heaters cannot produce the approximate 3-gpm requirement for whole-house water heating without exceeding the standard's 12-kW input maximum. A few units can achieve greater than 3 gpm, but require electric service over 100 amps. Many homes may only have 100 amps of service available, making electric instantaneous water heater applications difficult. The current water heater test procedure states that such a water heater can only produce 1.06 gpm at the 12-kW maximum input, which is far below the requirements for a whole house.

The DOE test procedure simply reserves the term *electric instantaneous water heater* and does not define it further. As the market grows for these units, DOE may consider them for a new test procedure and standard. Given DOE's stance on electric instantaneous water heaters, the ENERGY STAR water heater criteria are not likely to include these units. Without adequate product offerings in the marketplace, electric instantaneous water heaters are impossible to evaluate. Additionally, these water heaters are impractical for most homes given the immense electrical requirements for whole-house service.

Storage Water Heater Economics

Research was conducted to find the estimated price premium and typical payback for each type of water heater. Collecting reliable pricing data is difficult since nearly half of all water heater sales are through contractors. One major manufacturer, Bradford White, only sells through contractors. For gas and electric water heaters, price data were taken from two major retailers. Units that were made by the same manufacturers with the same volume and other similar criteria (except for energy factors) were compared. *These price comparisons should only be considered preliminary since they were based on a limited data set and since prices will be affected by implementation of the new Federal standard*. DOE expects that with the new Federal standard coming into effect, the prices of models meeting the minimum standard may increase. DOE welcomes additional feedback from stakeholders on this topic.

Electric Storage

A typical 50-gallon standard electric storage water heater with an energy factor of 0.90 was compared to a 50-gallon ENERGY STAR unit with an energy factor of 0.94. The purchase price of the standard model was $280; the purchase price of the ENERGY STAR model was $320. The annual energy cost of the standard model using national average utility rates was $411; the annual energy cost of the ENERGY STAR model was $393. Therefore, the price premium is $40 and the payback is just over 2 years.

Gas Storage

A typical 40-gallon standard gas storage water heater with an energy factor of 0.578 was compared to a 40-gallon ENERGY STAR unit with an energy factor of 0.632. The purchase price of the standard model was $270 and the purchase price of the ENERGY STAR unit was $380, for a price premium of $110. The annual energy cost of the standard model was $160 and the annual energy cost of the ENERGY STAR model was $146. The payback period is just under 8 years.

Gas Instantaneous Economics

Gas instantaneous water heaters are the newest type of water heater in the American market. Estimated sales of these units are 50,000 per year; annual sales increases are estimated at 30% to 50%. Comparing a gas instantaneous water heater with the standard Federal minimum energy factor of 0.62 to a unit with the potential ENERGY STAR energy factor of 0.82 yields annual savings of $36. Only five major manufacturers are offering gas instantaneous water heaters, making the estimate of a capital cost premium difficult. Using an estimate of $900 for the federally compliant unit and $1,100 for the potential ENERGY STAR unit, the simple payback of the potential ENERGY STAR gas instantaneous water heater is 5.5 years.

2. ENERGY STAR Water Heater Criteria for the Best-Performing Gas and Advanced Electric Water Heating Technologies

Scope

Another option for ENERGY STAR water heater criteria would be to include only the advanced water heating technologies (solar and heat pump) for the electrical storage product class, but use the best-performing gas instantaneous and gas/oil storage water heating products in their respective product classes. This option would promote advanced electrical water heating technologies and produce greater energy savings compared to using the best-performing electrical resistance storage water heater. For gas/oil technologies, the potential energy savings would remain the same. At this time, no advanced technologies exist for gas/oil water heaters comparable to solar or heat pump in the electrical product classes.

The energy consumption of electric resistance water heaters may be 100% more than that of heat pump, solar, or gas water heating methods. Setting the energy factor for electrical water heaters above 1.0 would force consumers interested in ENERGY STAR qualified water heating products to consider heat pump or solar water heaters where only electric service is available. The ENERGY STAR water heater criteria could also advise consumers and contractors to consider heat pump or solar systems only where gas is unavailable.

ENERGY STAR water heater criteria offer a unique opportunity to give widespread credibility and market awareness to both solar and heat pump technologies. Consumers could also be educated on the benefits of using gas, oil, solar, or heat pump technologies versus electrical resistance. The ENERGY STAR criteria may lead to increased demand for these products, although the increased capital cost of heat pump and solar water heaters would make these products too expensive for many consumers. Greater demand could prompt manufacturers to reconsider making heat pump water heaters, as they did in the 1980s. At a recent heat pump water heater workshop, manufacturers said they might be interested in resuming production of these water heaters if annual sales of over 50,000 units could be achieved.

Solar water heating systems still rely heavily on resource acquisition programs from government and utilities. Enacting an ENERGY STAR water heater program for solar water heaters may provide further incentive for both parties to give greater attention to solar water heating technology.

Potential Performance Criteria

Using an $EF_{electrical} > 1.0$ (or possibly a higher level) for electric water heaters while including only best-performing gas/oil water heaters would leave out nearly half of the established water heater market, but may offer much greater national energy savings. Below is a summary of the potential savings using a typical advanced electrical water heating technology (solar and heat pump) energy factor of 2.7. Solar water heater and heat pump water heater annual shipments are projected at 50,000 each, a minimal value suggested by industry making mass production more feasible. Combining these projections, the resulting 100,000 units are about 1% of all current water heater shipments. Solar and heat pump water heaters would replace conventional electrical

resistance water heaters. This shipment figure is simply a modest projection to demonstrate the potential impact advanced water heating technologies may have.

Product Class	Energy Factor	Potential ENERGY STAR EF for Common Size (gallons)	National, Annual Savings (GBtu*)
Electric Storage	$1.0	2.7 (50 to 80)	1,095
Gas Storage	$0.696-0.0017*volume	0.63 (40)	814
Gas Instantaneous	$0.82	0.82 (NA)	29
Oil Storage	$0.613-0.0017*volume	0.56 (30)	4.9

*Note: Heat pump water heater and solar water heater savings are calculated against a 50-gallon electrical storage unit, the most common electrical product.

The potential national energy savings of 1.9 TBtu-site are based on just 1% SWH and HPWH market share and 10% gas/oil market share. No advanced gas/oil technologies exist comparable to solar and heat pump in the electrical product classes so their contribution to national energy savings remains at the best performing scenario levels. The advanced electrical/best performing technologies gas/oil savings are greater than the 1.1 TBtu-site achieved by simply applying an improved energy factor to conventional electric resistance and gas/oil-fired water heaters.

The increase in aggregate energy savings of the advanced electrical/best performing gas/oil scenario is mainly a result of the tremendous individual product savings of a solar or heat pump water heater over the conventional electrical resistance unit. The savings of advanced water heater technologies over a conventional electric resistance water heater per installation may be in the range of 3000 kWh annually. This tremendous savings potential is much greater than the typical 100 kWh annual savings estimated by simply using the better performing electrical resistance water heater. Even at 1% market share, the advanced technologies national energy savings contribution is dramatically improved.

The gas and oil water heater savings and performance levels are calculated using current conventional technology levels for comparison purposes. There is a limited supply of products that significantly exceed the new Federal standard, so projecting future performance levels for the best-performing gas and oil technologies is difficult. As the market offerings adjust to the new Federal standard or any new technology, the aggregate energy performance will increase. The proper level will be reevaluated in the future based on the aggregate energy performance at that time. Again, the Department is interested in formal commentary on the potential energy factor levels for all water heating technologies so that it can more accurately determine ENERGY STAR energy factor levels in the future.

Alternative Storage-Type Water Heater Technologies

Both solar and heat pump water heaters use storage technologies, but the current Federal standard does not define separate product classes for them. Each system uses basic storage technology, but heats the water using either solar energy or energy delivered from the

surrounding space by a heat pump. Both solar and heat pump technologies typically use large storage tanks, although solar may use an integral storage tank. Since these water-heating technologies are also most commonly backed up with electrical resistance, the current electrical storage-type product class of the Federal standard best applies to each technology. DOE has rejected past petitions to create separate product classes for these technologies, reasoning that they are simply electrical storage products.

Solar Water Heaters

The Solar Rating and Certification Council (SRCC) administers the rating for solar water heaters. SRCC applies the standard, *OG-300, Certification of Solar Water Heating Systems*, to participating water heater companies. This standard expresses energy performance by the solar energy factor, defined as the quotient of the heat delivered to the storage tank divided by the heat supplied by the backup system (typically electrical resistance) plus the energy of the parasitic equipment (pumps, controls). The equation is shown here,

$$SolarEnergyFactor = \frac{Q_{delivered}}{Q_{parasitic} + Q_{auxiliary}}$$

where $Q_{delivered}$ is the energy delivered to the hot water load, $Q_{parasitic}$ is the pumping and control energy, and $Q_{auxiliary}$ is the energy used by the back-up equipment with the solar system operating.

The greater the solar energy factor, the more energy the solar collector supplies to the water. Typically, systems with larger collectors have higher solar energy factors. Note that even if the energy delivered by the solar collector were zero, the energy for the parasitic equipment would also be zero (since no pumping would be required) and the performance of the system would revert to that of a conventional electric storage water heating system. The collector will always deliver energy, unless the system itself fails. Because any solar water heater system will use less energy than a conventional storage system, any solar water heating system can be included as an ENERGY STAR qualified product.

To ensure quality performance, only systems rated with the SRCC's solar energy factor and listed in the SRCC's *Directory of Certified Solar Water Heating System Ratings* would likely qualify for an ENERGY STAR label. The SRCC directory clearly lists all participating companies and their system types. The directory separates gas- and electric-backed systems and applies solar energy factors separately.

Another term used to discuss solar water heater systems is the solar fraction, defined as follows:

$$SolarFraction = 1 - \left(\frac{EnergyFactor}{SolarEnergyFactor} \right)$$

The energy factor is simply the value for the conventional back-up storage tank used on the system. It is assumed to be 0.6 for gas or 0.9 for electric back up. A greater solar fraction means the solar system supplies more energy to the water. Note that whenever the solar fraction is greater than zero, the solar water heater system outperforms any conventional storage system. Increased solar energy factors at a given energy factor will result in higher solar fractions. The solar fraction is typically used to express energy savings of solar water heater systems over conventional systems. The greater the solar factor, the more quickly the user will realize an economic payback on the solar water heater as well.

The Energy Policy and Conservation Act (EPCA) require a product to be technically feasible to be considered for a standard. Interestingly, the latest water heater standard did not consider solar water heaters at all. The DOE test procedure mentions that solar water heaters would not be given a separate product class and would simply be considered storage-type water heaters. One company petitioned DOE to consider requiring a solar fraction minimum of 0.5, but DOE rejected this.

The solar fraction could be specified at a minimum level for future rounds of ENERGY STAR water heater criteria, elevating the performance of solar water heater systems significantly above conventional systems. This is how other market transformation or resource acquisition programs specify solar water heaters, ensuring that they greatly outperform conventional electric resistance water heaters.

Heat Pump Water Heaters

Heat pump water heaters are storage-type water heaters that supply heat to the water using a vapor compression cycle. The vapor compression cycle extracts available heat from the ambient air and moves it into the water. The vapor compression cycle benefits the surrounding space in the cooling season with added cooling capacity and dehumidification. Since heat pump water heaters use a vapor compression cycle as the primary supplier of heat, their energy factors are all greater than 1.0, with many exceeding 2.0. Conventional electric resistance elements back up heat pump water heaters for times of high demand or vapor compression failure.

The latest water heater standard declared heat pump water heaters technically unfeasible and did not consider a separate product class for them. However, this technology has superior energy efficiency. Since it uses storage technology, the Federal standard allows it to qualify as a storage-type water heater. The DOE test procedure modified the definition of heat pump water heaters to include heaters both with and without storage tanks. To date, only one manufacturer lists a heat pump water heater in the latest GAMA directory using the Federal test procedure and meeting the Federal minimum performance.

The recent trend in design is to downsize the compressors and let them run longer for recovery. A typical compressor may have a 4.5 to 6.0 kBtu/hr capacity. This leads to lower energy consumption and reduced noise levels. A positive consequence of using a vapor compression cycle is dehumidification of the space around the heat pump water heater. The added heat load in the heating season is a negative consequence, although the energy benefit of this water heater typically outweighs the added space-heating requirement. Many groups marketing heat pump

water heaters do not recommend using them in spaces with electrical resistance heat. Since this is the most expensive form of space heating, the added heat load of the heat pump water heater may reduce its cost effectiveness.

Noise was once a consideration for these water heaters. In the early days of production, many had objectionable noise levels. Today, units have smaller compressors with lower noise levels, similar to that of a room air conditioner, making them suitable for use in conditioned spaces in homes.

Alternative Water Heater Technology Economics

Heat Pump

A common heat pump water heater with an energy factor of 2.37 was compared to a 50-gallon standard electric storage water heater with an EF = 0.90. Including the installation of each type of water heater, the cost of the heat pump water heater was $1,350, while the cost of the standard electric storage water heater was $430. The annual energy cost of the heat pump water heater was $156, while the annual energy cost of the standard water heater was $411. The yearly savings are therefore $255 and the payback period is 3.6 years.

Solar

It is more difficult to estimate the costs and payback period of a solar water heater since several parts of the system must be considered. The energy usage of the solar water heater also varies greatly by climate since the unit will use electricity if solar energy is not available. The typical solar water heater suitable for a moderate climate (forced circulation) costs about $3,000 for the system, $1,090 for the tank, and $1,000 for the installation, for a total of $5,090. The solar water heater has an energy factor of 2.4, with a total annual energy cost of $154. Compared again to the 50-gallon standard water heater with an energy factor of 0.90, an installed price of $430, and an annual energy cost of $411, the annual savings are $257 and the payback period is 18 years.

Options for Introducing the ENERGY STAR Water Heater Criteria

The two primary scenarios discussed above – best-performing conventional water heating technologies or advanced electrical/best-performing gas/oil water heating technologies – could be phased in over two or more years, allowing industry and the market to react to the proposals. Below are four optional ways to introduce the ENERGY STAR water heater criteria:

- Option 1:
    - Best-Performing Conventional Water Heating Technologies Criteria becomes effective January 20, 2004, coincident with the Federal standard
        - Advanced Technologies initially excluded
- Option 2

  - Best-Performing Gas/oil and Advanced & Conventional Electric Water Heating Technologies criteria becomes effective January 20, 2004, coincident with new federal standard
- Option 3
  - Best-Performing Conventional Water Heating Technologies Criteria becomes effective January 20, 2004, coincident with the Federal standard
    - Add advanced electrical water heating technology criteria in 2006 or later
- Option 4:
  - Best-Performing Gas/oil and Advanced Electric Water Heating Technology Criteria (excluding conventional electrical storage water heaters) is introduced on January 20, 2004 or later

The options presented above will require discussion among industry stakeholders to determine the best course of action.

Implementation Challenges for ENERGY STAR Water Heaters

ENERGY STAR's recommendations address energy use, but product quality issues are also of concern to consumers. In some ENERGY STAR criteria, product quality issues, such as a longer warranty period or added product testing, are addressed. The issues below are identified as major concerns for implementation. Any other issues that ENERGY STAR criteria should address should be included in commentary to the Department.

Fuel Switching

Heat pump water heaters are most economical when replacing an electrical resistance storage type water heater. The energy and economic performance of a heat pump water heater versus a conventional gas storage-type water heater may not be significantly better. Burning a fuel (oil or gas) on site is one of the most efficient ways to heat water or condition a space. Using a heat pump water heater at a site where gas is available may not be recommended. Currently, NYSERDA's heat pump water heater program makes this recommendation. Rebates are not allowed when only gas is available. A rare exception is made when a permit for a gas water heater could not be obtained and only an electric water heater can be used.

Solar water heaters may not be cost effective compared to conventional gas storage technology either. Again, burning a fuel on site is economically attractive. Replacing a gas storage water heater with a solar water heater, even if it is backed with a gas-fired storage tank, may not be economical. Replacing conventional electrical resistance storage tanks with solar water heaters may be a primary recommendation of ENERGY STAR water heater criteria.

Usage

Customers with little hot water usage (such as a single or double occupant of a home) may not see the economic benefit of either a heat pump water heater or solar water heater versus conventional electrical storage technology. However, ENERGY STAR has not considered sizing issues for any of its products where energy usage varies with occupancy or duty.

ENERGY STAR simply specifies the best energy performance for a given product based on common operating conditions. DOE assumes 64.3 gallons a day for the typical home and uses this figure in its standard to rate units with the energy factor. Accounting for a customer's usage would require a schedule or map of energy factors by usage, a difficult process whose results could be confusing for the consumer.

Market Infrastructure

The market for gas instantaneous water heaters, solar water heaters, and heat pump water heaters is underdeveloped, as is the infrastructure for purchasing these units. Most consumers will not be able to buy such water heaters by calling a plumber or visiting their local hardware store. Promotional efforts with contractors and retailers will be necessary to educate them about the benefits of these products and procedures for purchasing them. Working with new construction efforts or linking with market transformation programs may be the best opportunity for an ENERGY STAR program for gas instantaneous, solar, and heat pump water heaters.

Given the added capital cost of these water heaters, incentives from market transformation efforts or discounts to construction firms or builders may enhance the success of an ENERGY STAR water heater program. The Hawaii Electric Company commented that solar water heater sales drop drastically if any government or utility subsidy ends.

Added Heat Load

Some language may have to accompany ENERGY STAR criteria to ensure that users apply heat pump water heaters correctly. Heat pump water heaters add heating load when placed in a conditioned space. The Department recommends cautioning consumers against using heat pump water heaters when electrical resistance heaters are in the space.

Sizing Instantaneous Water Heaters

The sizing of instantaneous water heaters has been given little attention in the current Federal standard. These products were added to the standard with little study because of their small market share. The governing term for them is maximum GPM flow rating. The current Federal standard suggests that a flow of 3 to 5 GPM is adequate for whole-house application of a water heater. Most of the instantaneous water heater products listed with the Federal Trade Commission are > 2.5 GPM. Consumers should be informed about the performance of these water heaters. For intense requirements above the maximum flow rate, output temperature may be depressed. Many sizing scenarios presented by manufacturers simply refer to the operation of one, two, or three water-heating-dependent devices as the method for selection.

As mentioned earlier, gas instantaneous water heaters place much greater demand on the gas supply line. Caution in applying these products is warranted to ensure adequate capacity for all gas-consuming appliances in a home. Consumers need to consult with an expert when applying these products, especially in older homes to ensure that their gas infrastructure will support the application of a gas instantaneous water heater. Local gas utilities may be able to help the consumer apply these products.

Reliability

Heat pump water heaters have had a poor reputation for reliability in the past. Successfully marketing these products as part of an ENERGY STAR water heater program may require including a longer warranty period, especially for the vapor compression system. Participants at a recent heat pump water heater workshop concluded that a two-year parts warranty on these units might be necessary to ensure consumer confidence. Labor warranties were also discussed. Since the heat pump water heater is a special device, a broad range of skills, including knowledge of HVAC systems, is required, making repairs potentially expensive and contractors hard to find. Marketing for the heat pump water heater may have to include information on the risks of repair.

Summary

Nationally, residential water heaters consume 2.97 PBtu (Quads-primary), about 15% of all household energy consumption. Their energy consumption is second only to space heating in a typical home. The table below models the annual operating energy consumption of each water heater product class for the best performing scenario. The annual energy consumption at the new federal minimum level is calculated first. Since energy consumption is based on tank volume, the weighted average-volume for each product class was used. The weighted average volume was taken from the latest water heater technical support document. The annual operating energy consumption of each unit at the minimum potential ENERGY STAR level is then calculated at the same weighted average volume. The difference in these values yields the annual ENERGY STAR savings.

For projecting national energy savings, a 10% market penetration of conventional ENERGY STAR products was assumed. The exceptions to the 10% market penetration are heat pump and solar water heaters. Current heat pump and solar water heater sales volumes are small and are unlikely to increase dramatically under this scenario with ENERGY STAR qualified conventional storage equipment available. Only the current, estimate sales volumes of these products were used since they would become ENERGY STAR qualified immediately under this scenario. Solar and heat pump water heater performance was compared to a typical 50-gallon electric storage unit because this kind of unit would likely be replaced. Typical energy factors for solar water heaters and heat pump water heaters were used for these units. Total annual savings are about 1.7 TBtu, primary. Note that the savings of the heat pump water heater and solar water heater versus the more efficient electric storage units are nearly half of the total electrical energy savings at a small fraction of the shipments. Their dramatic energy savings contribution demonstrates their superior energy performance characteristics.

Product Class	Weighted Average Volume	10CFR minimum Energy Factor, EF, using Weighted Average Volume	Average annual unit consumption, kWh (elec.) or mmBtu (gas)	Potential Minimum Energy Star level, EF, using Weighted Average Volume	Average annual consumption, kWh (elec.) or mmBtu (gas)	Annual Operating Savings,kWh (elec) or mmBtu (gas)	Shipments @ 10% Market Penetration	National Electrical Savings, GWh	National Savings, Mbtu
Electric Storage	42.80	0.914	4,807	0.934	4,699	107.7	432,700	46.6	158,996
Gas Storage	41.00	0.592	25.3	0.627	23.9	1.4	586,237		814,458
Oil Storage	33.23	0.527	28.4	0.550	27.2	1.2	4,163		4,952
Instant, Gas Fired	-	0.620	24.2	0.820	18.3	5.9	5,000		29,468
Heat Pump	50.00	0.904	4,857	2.400	1,830	3,027.7	2,000	6.1	20,661
Solar	50.00	0.904	4,857	3.000	1,464	3,393.6	7,000	23.8	81,053
Total, Electric								76.4	260,710
Total, Site									1,109,587
Total, Primary									1,683,148

Below, the above table is repeated with new assumptions to model the potential savings of the advanced electrical/best-performing gas/oil water heating technologies scenario. In this scenario, savings from conventional electrical storage water heaters are now zero since these units would not be ENERGY STAR qualified. The savings from heat pump water heaters and solar water heaters are estimated at the modest market share of approximately 1% (100,000 units). All the other assumptions for gas and oil water heaters described above are the same.

Product Class	Weighted Average Volume	10CFR minimum Energy Factor, EF, using Weighted Average Volume	Average annual unit consumption kWh (elec.) or mmBtu (gas)	Potential Minimum Energy Star level, EF, using Weighted Average Volume	Average annual consumption kWh (elec.) or mmBtu (gas)	Annual Operating Savings,kWh (elec) or mmBtu (gas)	Shipments @ 10% Market Penetration	National Electrical Savings, GWh	National Savings, MBtu
Electric Storage	NA								
Gas Storage	41.00	0.592	25.3	0.627	23.9	1.4	586,237		814,458
Oil Storage	33.23	0.527	28.4	0.550	27.2	1.2	4,163		4,952
Instant,Gas Fired	-	0.620	24.2	0.820	18.3	5.9	5,000		29,468
Heat Pump	50.00	0.904	4,857	2.400	1,830	3,028	50,000	151	516,523
Solar	50.00	0.904	4,857	3.000	1,464	3,394	50,000	170	578,947
Total, Electric								321	1,095,470
Total, Site									1,944,347
Total, Primary									4,354,382

Again, the individual, annual solar and heat pump water heater energy savings over conventional electrical storage are approximately 3,000 kWh. Coupling this fact with the market penetration of just 1%, new national savings of 4.3 TBtu-primary are possible. These savings are dramatically greater than the 1.7 TBtu-primary from the best performing gas/oil and electric scenario.

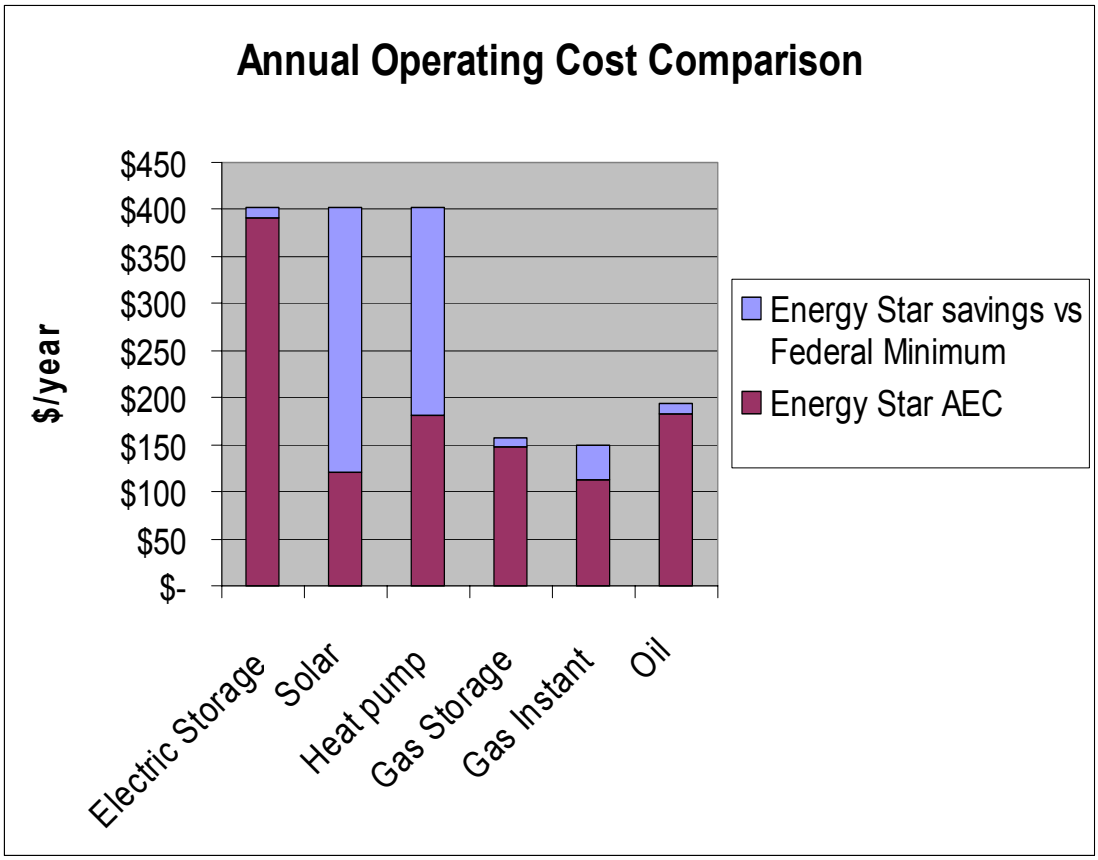
Including heat pump and solar technologies in either proposal will help educate the public on the tremendous energy-saving potential of these advanced technologies.

Below is an economic analysis summary of all the water heating technologies and product classes. Note, solar and heat pump technologies are compared to a conventional, federally compliant electrical storage unit, the most likely unit these technologies would replace. Installation costs for solar and heat pump are much greater than for that of conventional storage equipment. Therefore, installations costs are included in these comparisons only. For the electric/gas storage and gas instantaneous units the installations cost are identical and therefore not necessary. Again, these are approximate, preliminary costs. Product offerings are rapidly changing and widely varying.

Product Class/Technology	Approximate Cost-Fed Min.	Approximate Cost-ENERGY STAR level	Annual Operating Cost Savings	Approximate Payback Period
Gas Storage	$270	$380	$14	8
Gas Instantaneous	$900	$1,100	$36	6
Electric Storage	$280	$380	$12	2
Solar	$430*	$5,090*	$257	18
Heat Pump	$430*	$1,350*	$255	4

*Installed costs

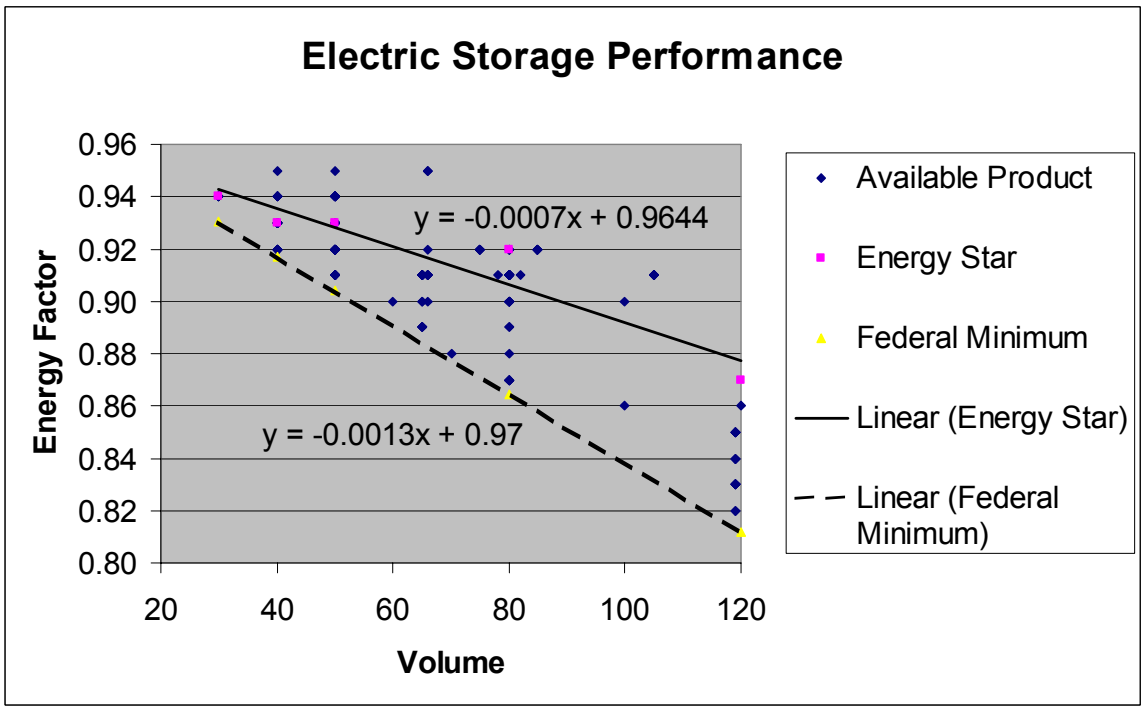
Finally, the typical annual operating cost and potential savings for the major water heating technology/product classes are presented in the following graph. On each technology/product class's bar, the shaded portion of the top of the bar depicts the potential cost savings for the best performing gas/oil and electrical technology proposal. The savings are modest for electric storage, gas/oil storage, and gas instantaneous. The savings are dramatic for solar and heat pump since they are compared to a conventional electrical storage water heater. The graph also shows the incremental operational expense of electric resistance water heating versus all other water heating technologies: gas instantaneous, gas/oil storage, solar, and heat pump water heaters. Simply ignoring the electric storage bar in the graph depicts the cost savings of the second scenario presented, best performing gas/advanced electrical water heating technologies. In this scenario, advanced electrical water heating technology's operational cost is comparable to gas/oil technologies.

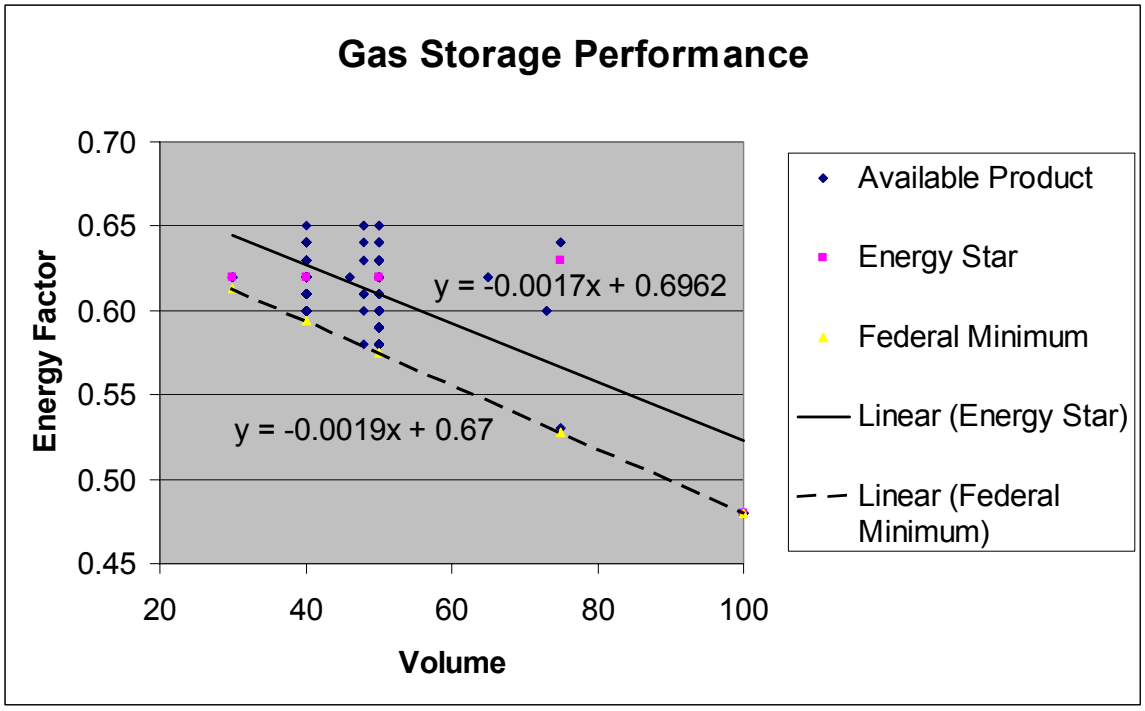


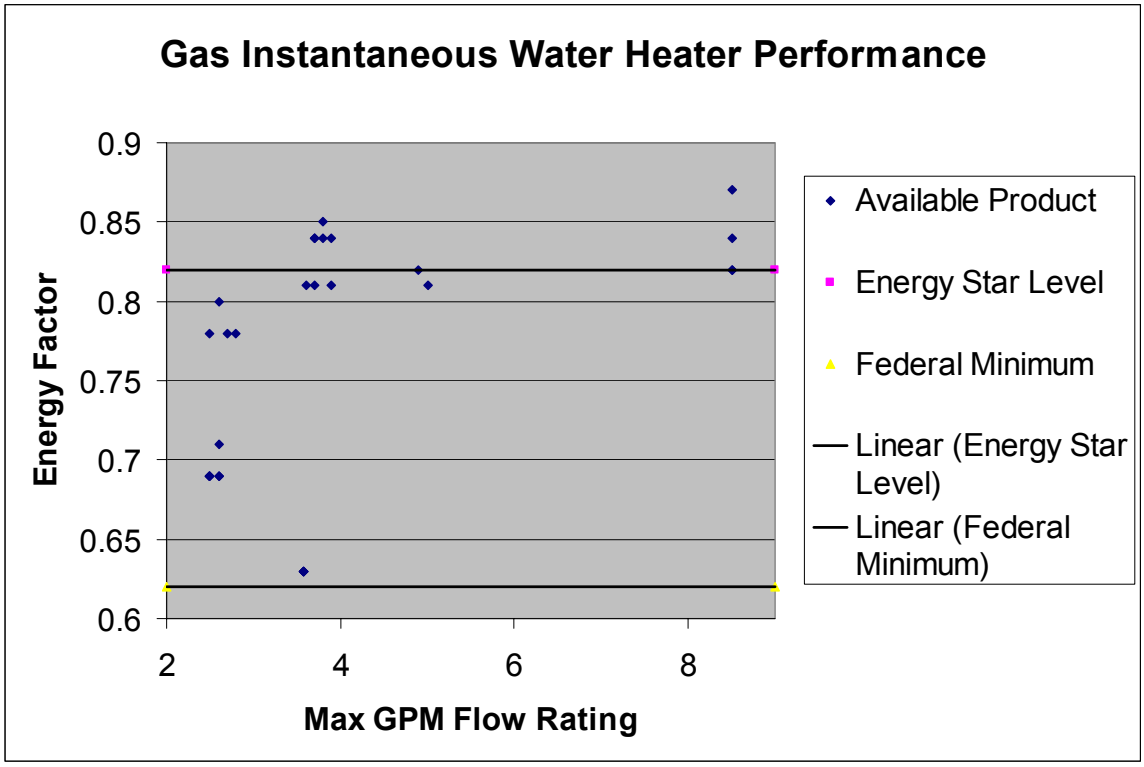
AEC=annual energy consumption

Appendix

Technical Analysis and Performance Graphs







Updated Federal Water Heater Standard, 10 CFR 430

On January 17, 2001, the U.S. Department of Energy issued a final rule increasing the minimum performance limits for water heaters. This rule replaces the previous ruling in 1991. Manufacturers are now in the process of modifying their product offerings to meet the effective date of the new standard, January 20, 2004. In this new standard, several changes occurred:

- New tabletop product class added: Performance levels left at 1991 standard's electric storage level
- New gas and electric instantaneous water heater product classes added: Performance levels at 1991 storage-type standard's levels
- Increased electric and gas storage-type performance levels

DOE increased the minimum energy factors for storage-type units. The results of this performance increase indicate that electric storage units will save 188 kWh/year/unit and gas storage types will save 22 therms/year/unit. On a national aggregate basis, the new standard will save 4.6 PBtu (quads) in 26 years, or approximately 177 TBtu per year.

DOE added the tabletop product class to ensure that these smaller units could be replaced with similar units. Increasing the performance on tabletop units may have resulted in an increase in the size of the product, making replacement difficult. Tabletop units are defined to be 36 inches high, 25 inches deep, and 24 inches wide.

Both gas and electric instantaneous water heaters were added to the Federal standard with no significant performance evaluation noted. The market for these products was small at the time the standard was issued and an evaluation was not deemed necessary. These products will be given more attention as their respective markets develop.

U.S. Department of Energy Water Heater Product Class Definitions

Product Class	Minimum Volume	Maximum Volume	Maximum Energy Input*
Electric storage	20	120	12 kW
Heat Pump	20	120	6 kW
Tabletop	Electric Storage type with dimension < 36”x25”x24”		
Electric Instantaneous	DOE has reserved this category for future use.		
Gas Storage	20	100	75,000 Btu/hr (22 kW)
Oil Storage	20	50	105,000 Btu/hr (30 kW)
Gas Instantaneous	NA	2	200,000 Btu/hr-59 kW (50,000 Btu/hr minimum-15 kW)

*Controlled maximum output temperature < 180°F for all product classes.